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Implementation of Wireless Input Methods (Game Controllers and Accelerometers) for Simulated Weapon Trigger Fire in the Computer Assisted Rehabilitation Environment (CAREN)

Relevance to Operational/Navy Medicine

Variations of the CAREN system are installed and used at four locations in the U.S. Department of Defense: NHRC, Walter Reed National Military Medical Center, Brooke Army Medical Center, and the National Intrepid Center of Excellence.

Key Words

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Summary of Media-Sensitive Subject Matter

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Harvey Edwards, B.S., Delwin Johnson, M.S., Pinata Sessoms, Ph.D.
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Introduction

The Computer Assisted Rehabilitation Environment (CAREN; Motek Medical BV, Amsterdam, The Netherlands; Figure 1) located at the Naval Health Research Center is an immersive virtual environment and motion analysis laboratory designed for interactive rehabilitation and research of human performance in a controlled and repeatable environment. The DoD uses the CAREN system for clinical rehabilitation and research at three locations: Walter Reed National Military Medical Center, Brooke Army Medical Center, and the National Intrepid Center of Excellence. The Naval Health Research Center (NHRC) also houses a CAREN system, with the primary purpose of conducting research for the advancement of treatment and rehabilitation practices in the CAREN and other interactive environments. NHRC creates and tests accelerated rehabilitation programs, and conducts physical and cognitive performance testing under virtual conditions relevant to the warfighter.

Figure 1. Computer Assisted Rehabilitation Environment (CAREN).

The CAREN requires control software in order to manipulate and monitor the hardware components, activate events, record information, and create virtual scenarios. The CAREN D-Flow control software (Motek Medical BV, Amsterdam, The Netherlands) allows the operator to create, modify, and operate virtual scenarios. It incorporates different modules from which to manipulate and monitor the hardware components, activate events, and record information. The CAREN system at NHRC was originally equipped with a plastic rifle that could simulate weapon fire onto the screen while submerged in this virtual environment. The trigger for this weapon had a switch wired to a simple wireless presentation remote (F2 button) in order to communicate with the CAREN D-Flow control software. Although

somewhat effective, this simulated weapon style and trigger fire method were neither realistic nor durable enough for repeated use in this type of virtual environment. In order to solve this problem, both the weapon and the method of wireless trigger fire communication needed to be improved. The purpose of this paper is to report the method for creating an effective and realistic shooting mechanism for the CAREN system.

Figure 2. KWA CQR MOD1 M4 simulated weapon.

Method

Before determining an appropriate means for wireless trigger fire communcation to the D-Flow control software, a suitable simulated weapon, with realistic weight and feel, was required. The Airsoft KWA CQR MOD1 M4 simulated weapon was chosen with a Picatinny rail system installed (KWA Performance Industries Inc., City of Industry, CA; Figure 2) for initial testing. Along with its realistic weight, look, and feel, this simulated weapon also has motorized internals that create small amounts of recoil and sounds, making it an excellent fit for this virtual environment. While this simulated weapon has the physical characteristics of a real weapon, it has no means to communicate trigger fire to the CAREN D-Flow control software. Using this weapon, two ways of sending trigger fire response to the D-Flow software were proposed. One was to integrate a wireless game controller within the weapon, and the other was to measure the acceleration caused by the recoil of the weapon to trigger a response.

Figure 3. Trigno EMG wireless accelerometer.

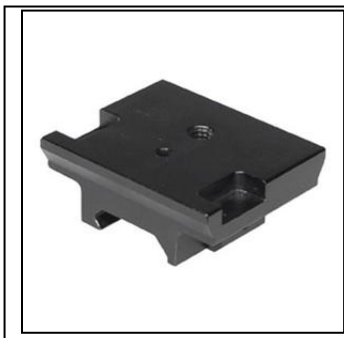

Figure 4. Vortex Optics Picatinny Rail Tripod Adapter Mount.

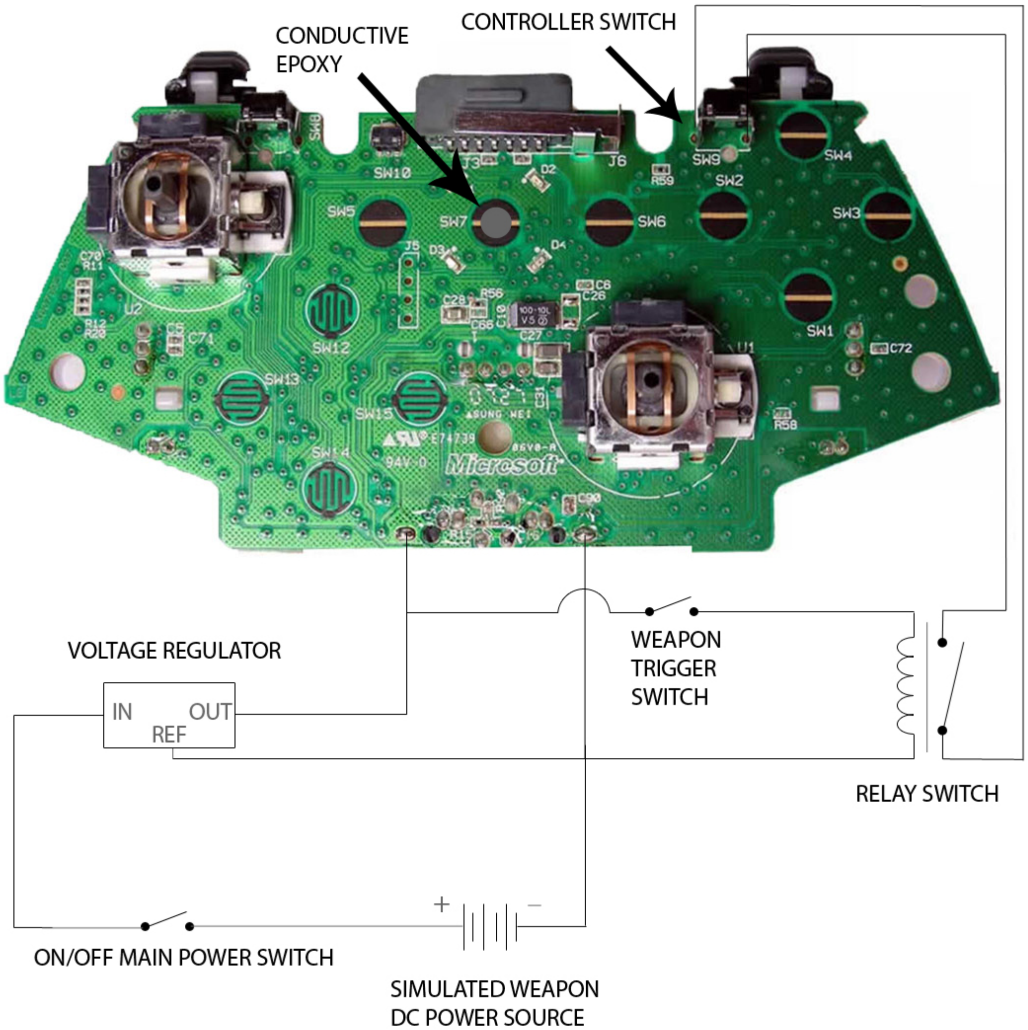

Figure 5. Wiring diagram for wireless gaming controller.

Wireless Game Controller

The CAREN D-Flow software reads inputs sent by wireless game controllers that are recognized by Microsoft Windows (Plug and Play). Two models have been utilized that work well within the D-Flow software. These are the Logitech Cordless Rumblepad 2 (Logitech International, S.A., Romanel-sur-Morges, Switzerland) and the Xbox 360 wireless controller for Windows (Microsoft, Redmond, WA). The circuit board of either controller can be removed from the controller case. The portion that activates the trigger buttons can be rewired into the gun so that when the trigger is pulled, the trigger switch is activated and sends a signal to the D-Flow computer (Figure 5). This can then be programmed in D-Flow's controller module to activate an event (i.e., trigger fire) in the D-Flow application. When rewiring the circuit board of the game controller, care must be taken to keep the antenna intact so that it can wirelessly send the signal to the receiver that is plugged into the D-Flow computer. The power to the

circuit board can either be run from the original battery pack that is part of the game controller (though this may be hard to integrate with the simulated weapon), or the power can be rewired to utilize the battery pack that drives the motor of the gun. In the M4 weapon, these components can be placed inside an empty magazine. It is convenient to mount a switch that can power on and off the game controller so that the batteries do not drain (though these devices will time out after approximately 10 minutes of inactivity).

Accelerometer Input

Figure 6. Custom plastic sensor mount. The accelerometer should fit snugly within the mount and the mount should be secured to the Picatinny Rail Mount so there is no noise that is not from the weapon being fired.

The second method of measuring a trigger response of the weapon is to use the acceleration caused by the simulated weapon's recoil to send an event or trigger fire to the CAREN D-Flow control software. In order to complete this, a Trigno EMG wireless accelerometer (Delsys Inc., Boston, MA; Figure 3) was attached to the exterior of the weapon along the Picatinny rail system using a Vortex Optics Picatinny Rail Tripod Adapter Mount (Vortex Optics, Middleton, WI; Figure 4) with a custom plastic sensor mount (Figure 6) to hold the accelerometer snugly in place. The Trigno EMG wireless accelerometer can measure accelerations (x, y, and z) in real time and communicate it to the D-Flow control software using a wireless analog signal. Recoil acceleration in simulated weapons occurs in a direction parallel to the barrel of the weapon, so the accelerometer should be mounted to capture the movement in this direction. Mounting the Trigno accelerometer in the fashion shown in Figure 7 allows for this acceleration to be measured in the y direction in respect to the EMG sensor axes.

The signal from this sensor is sent wirelessly (2.4 GHz band) to the Trigno base station. This base station has an analog output connector from which a DC-A22 cable is attached, which is in turn wired into an NI USB-6225 Multifunction DAQ module (National Instruments, Austin, TX). The signals from this A/D device are read into the motion capture software, Cortex (Motion Analysis Corp., Santa Rosa, CA) as analog signals, which is the method by which all analog data (e.g., force plate and EMG signals) are sent to Motek's D-Flow software in real time. Other wireless accelerometers and input methods could be used for this purpose, as long as the signal can be read into the D-Flow software in real time.

Figure 7. Sensor mounting position.

With the weapons used, the recoil produces a distinct acceleration signal, though other movements of the weapons could also produce similar accelerations. Measuring the changes in acceleration produced from the recoil in the direction the recoil occurs (e.g., the y direction as shown in the setup of Figure 6) during trigger pull with

the accelerometer, the signal was programmed into the D-Flow control software to register one weapon fire for every recoil cycle produced by the simulated weapon. To help distinguish recoil from random weapon movement (which is usually slower than the recoil movement), the second derivative of the acceleration was taken (Figure 8). The second derivative indicates the curvature, and thus the sharpness of the peaks, of the original acceleration function and thus serves to differentiate between actual firings and random weapon movements. This was done using the Lua scripting (The Pontifical Catholic University of Rio de Janeiro, Brazil) module included within the D-Flow control software (Appendix). With this "filtering" only those accelerations from the weapon's recoil were registered as a shot in the D-Flow control software. The KWA CQR MOD1 M4 simulated weapon has two modes of operation: semiautomatic and fully automatic. The accelerations caused by recoil in both modes are similar, thus the same Lua scripting is viable for both modes of operation.

Two other simulated weapons have been tested with success using this same method: an FN Herstal SCAR-L and an H&K MP5A5 Tactical (Airsoft Extreme, USA; Figure 9). Both of these weapons have slightly different accelerations due to recoil, but they can also be easily differentiated from the acceleration of normal movement of the simulated weapon. Because the acceleration response varies between weapons, movement of the user, and placement of the accelerometer, a threshold value is set

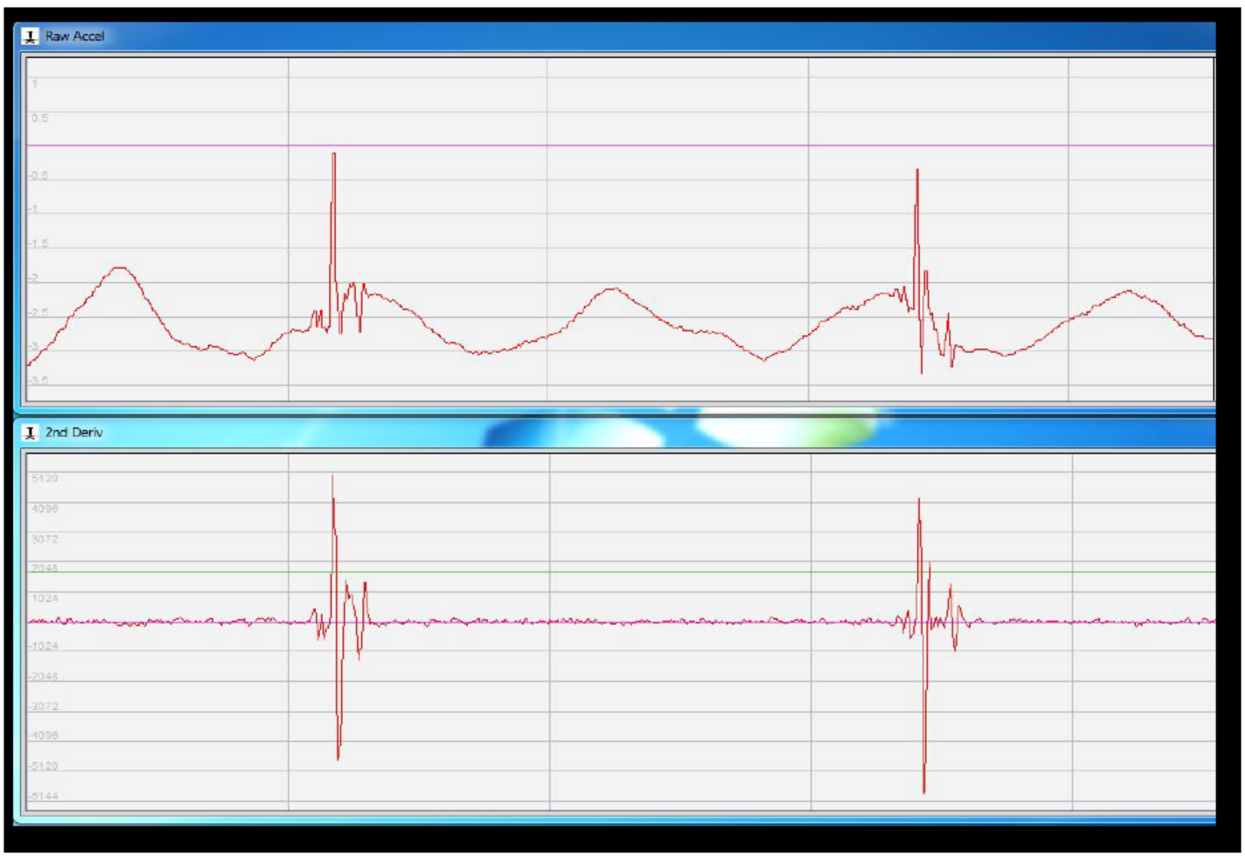

Figure 8. Example raw acceleration signal from the accelerometer (top graph) and the second derivative of the signal (bottom graph). A shot is registered in the D-Flow software when the filtered signal reaches the threshold (green line in bottom graph) that is set for each weapon and subject. In this figure, two shots are shown. A delay interval is set within the program to prevent a signal from registering as more than one shot (as in the second shot where the signal reaches the threshold value twice).

within the D-Flow software that the signal needs to meet before a shot is registered within the software (Figure 8). It is helpful to make this a variable within the D-Flow program that the operator can adjust to make sure the correct threshold is set. If the threshold is set too high, a trigger pull will not register as a shot. If the threshold is set too low, other movements of the weapon may register falsely as a shot.

Safety

It must be noted that any Airsoft-style simulated weapon has the capability to fire nonlethal plastic pellets. Though they are nonlethal, injury could occur along with damage to the CAREN projection screen. To avoid accidental fire of these pellets, it is recommended to remove the internals from the clips of any simulated weapon that will be used with the CAREN system and seal the pellet feed tube on the weapon. These measures will help ensure safety with this integration.

Results

Wireless Game Controller

Incorporation of a wireless game controller within a simulated weapon makes it easy to get a trigger signal from the weapon into D-Flow. The downside to this implementation method is that a controller must be installed in each weapon to be used in the CAREN system. Each controller will have its own receiver that connects with the D-Flow computer, so these must be clearly labeled so the operator knows which receiver belongs to each weapon. Also, if a wire or part disconnects or fails, the weapon must be disassembled in order to fix the problem, and this will require someone with knowledge in this area to address the problem. Finally, because the weapon must be rewired to incorporate the game controller, the recoil must be disengaged. This could cause the subject to feel less engaged in the scenario or it could be a problem if recoil is an important factor in measuring shooting accuracy.

Accelerometer Input

The implementation of wireless accelerometers for simulated weapon trigger fire in the CAREN system has been highly successful. One of the reasons for this success is due to the quick response time of the Trigno EMG wireless accelerometer sensors. The sensors produce an analog signal presented with a full nominal range +/-5 V. This signal can be read in real time, though it should be noted the data have a 96-

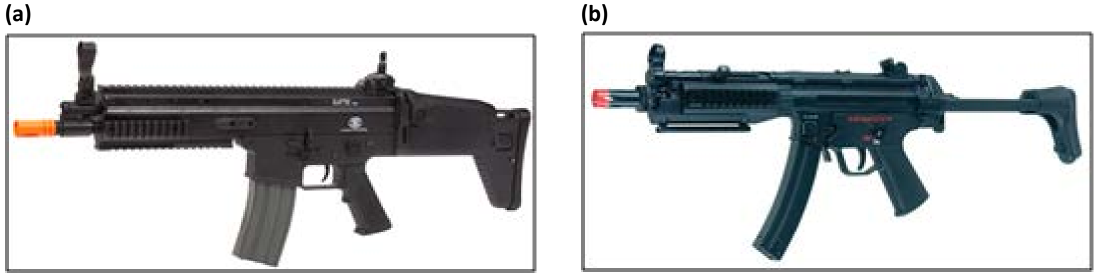

Figure 9. (a) FN Herstal SCAR-L, and (b) H&K MP5A5 Tactical simulated weapons.

ms delay from the time the sensor detects the event to the time the analog signal is produced. From the sensor, the signal is sent to the D-Flow control software via the Motion Analysis Cortex software almost instantaneously. This quick response time allows for recognition of weapon fire in the CAREN D-Flow control software to occur almost instantaneously with the trigger pull on the simulated weapon.

The consistent recoil from the simulated weapons also plays a part in the success of this integration. The trigger fire makes a very distinct and consistent pattern of acceleration. By taking the second derivative of this acceleration and using the Lua scripting module to determine these cycles and establish them as trigger pulls, weapon fire can be reasonably accurate for all types of Airsoft-style simulated weapons used in the CAREN system that have sufficient recoil. False shots can be made if the weapon experiences similar movements to that of when recoil of the weapon occurs (such as being pushed up against the shoulder quickly) or if the acceleration threshold is set too low. By tuning the system, accelerometer input for firing is an efficient and high-quality way of integrating simulated weapons into the CAREN.

Figure 10. Example of subject walking in the CAREN system with a simulated weapon.

Appendix. Lua Script for Sending the Trigger Fire Signal

Description

The Lua scripting code listed here is a small interpretive computer program that runs repeatedly in rapid succession, typically 100 to 300 times per second, with assigned variable values persisting between successive runs. Initial variable values are set in lines 12-22 only during the first running of the code. The Lua scripting complements the standard modular programming interface used with the CAREN.

Trigger inputs are either in the form of direct game controller trigger switches (lines 4-5) or an input from the second derivative of the EMG accelerometer (line 6). The value in line 7 determines the input switch selection, and line 8 is a threshold value to be compared with the EMG input.

The game controller switches are very simple in that they trigger a firing event and then remain dormant for specified rest interval of 80 ms (defined in line 14, controlled in line 41) before being allowed to fire again.

The EMG input is compared with the threshold value (line 27) as well as paced by a minimum shot time interval (line 28). The Boolean variable bResetEMG is also used to block multiple firing events from a single event.

Additional code in lines 62–82 is used to limit the number of firing events in a short period of time. The subject is penalized with a reloading time out if he or she fires more than 30 shots within a 10-second interval.

Code

```
1  -- The shot interval time must be longer
2  -- than the sound effect wave file.
3
4  tg5 = inputs.get("trigger 5")    -- game controller trigger
5  tg6 = inputs.get("trigger 6")    -- game controller trigger
6  emg = inputs.get("EMG accel")    -- 2nd derivative of EMG acceleration signal
7  sns = inputs.get("sensor")       -- trigger sensor selection (game controller or EMG)
8  thr = inputs.get("EMG thresh")   -- EMG threshold slider value (range is 0 to 1)
9  threshEMG = thr * 10000 -- minimum to shoot
10
11  -- initial values
12  if action() == "Start" then
13      totalShots = 0
14      interval = 0.08      -- seconds per shot
15      shotTime = interval -- time since last shot
16      bResetEMG = true
17      bTrigger = false
18      bReloading = false
19      burstCount = 0
20      burstTime = 0
21      burstStart = frametime()
22  end
```

```lua

-- select trigger input
if sns == 1 then
   -- trigger by EMG crossing threshold value
   if bResetEMG and emg > threshEMG then
      if shotTime > interval then
         bTrigger = true
         bResetEMG = false
         shotTime = 0
      end
   end

   if emg < 0 then
      bResetEMG = true
   end
else
   -- trigger by game controller buttons 5 or 6
   if tg5 == 1 or tg6 == 1 then
      if shotTime > interval then
         broadcast("Shooting Sound")
         bTrigger = true
         shotTime = 0
      end
   end
end


shotTime = shotTime + framedelta()  -- delay between successive shots
if bReloading then bTrigger = false end   -- this is a penalty mode for shooting too much

-- fire the shot if interval has expired
if bTrigger then
   broadcast("Shoot")
   burstCount = burstCount + 1
   shotTime = 0
   totalShots = totalShots + 1
   bTrigger = false
end

--  reload delay if shooting too much (some subjects just want to spray bullets....)
burstTime = frametime() - burstStart

if burstCount > 30 then
   if burstTime < 10 then
      broadcast("Reload Start")
      bReloading = true
   end

   burstCount = 0
   burstTime = 0
   burstStart = frametime()
end

```

```
-- release from penalty mode
if bReloading and burstTime > 5 then
   broadcast("Reload End")
   bReloading = false
   burstTime = 0
   burstStart = frametime()
end

outputs.set("burstCount", burstCount)
outputs.set("burstTime", burstTime)
outputs.set("total", totalShots)
outputs.set("shotTime", shotTime)
outputs.set("EMG thresh", threshEMG)
outputs.set("test", sns)
```

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14. ABSTRACT

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15. SUBJECT TERMS
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